Congratulations to New ICFO PhD graduate

Dr. Ivan Nikitskiy graduated with a thesis on "Photodetectors based on Quantum Dots and 2D Materials"

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Dr. Ivan Nikitskiy earned his Master in Physics from Lomonosov Moscow State University, before joining ICFO to pursue his PhD conducting research on the development of photodetectors using novel materials in the Functional Optoelectronic Nanomaterials and Quantum Nano-Optoelectronics groups. Dr. Nikitskiy?s thesis entitled "Photodetectors based on Quantum Dots and 2D Materials" was supervised by ICREA Professors at ICFO Dr. Gerasimos Konstantatos and Dr. Frank Koppens.

Abstract:

Photodetector is a key component of many technologies, since it converts light into electrical signals, which can be stored or further processed. Detection of light is instrumental in many applications and in a broad spectral range. The efficiency of infrared photodetectors is limited by the properties of conventionally used materials. Therefore, there is a great need to identify new materials to outperform the existing technologies and offer new functionalities. Two novel types of materials have shown great potential for photodetection: colloidal quantum dots (QDs) and two-dimensional (2D) materials.

QDs are nanoscale crystals of conventional semiconductors or metals that can be obtained by liquid-phase chemical synthesis and can be further processed in a solution. This offers a low-cost manufacturing and simple integration with various substrates, including flexible ones. The most peculiar feature of these materials is the tunable optical absorption through the quantum confinement size effect in semiconductor quantum dots. In this study we utilize lead sulfide QDs that allow efficient light absorption across the visible and infrared range, and provide trapping of the light-induced charge carriers that leads to photoconductive gain.

2D materials are one atom-thick individual planes of bulk crystals like graphite or molybdenum disulphide and offer ultimate thinness, flexibility, partial transparency and compatibility with microelectronic circuits. After a decade of development, many of these materials have become available by large-scale synthesis methods. Graphene, currently the most exciting example of the 2D materials, possesses gate-tunable electronic characteristics and caters for ultrafast response times due to the high mobility of charge carriers.

This work presents a novel type of photodetectors based on both QD and 2D materials. The hybrid structure of such devices allows to combine their unique properties. A layer of QDs is utilized to efficiently absorb the light in the selected wavelength range, while the underlying graphene or another 2D material serves as the charge transport layer of a photodetector. The first demonstration of hybrid QD-2D photodetectors has shown very good performance, but faces a few limitations that must be addressed before the technology could be used in commercial applications [3]. Despite this technological motivation, finding solutions to these problems requires a fundamental approach.

This research project studies the charge-transfer mechanism in the hybrid structures and generates multiple advances in performance optimization of this class of photodetectors. By applying an electric field across the light sensitizing layer we enhance the charge collection efficiency and dramatically increase the quantum efficiency of the devices. Engineering of the interface between the two materials grants control over the separation of light-induced charges and provides an improvement in sensitivity of the detectors. Implementing a 2D semiconductor instead of graphene as a charge transport layer allows to suppress the dark current and increase the on-off ratio in these hybrid devices.

In summary, this study merges the QD and 2D materials to create hybrid devices for broadband photodetection and offers new approaches to optimize their performance. To showcase the scalability of this technology all utilized materials were produced with large-scale synthesis methods. The demonstrated capabilities include video-frame-rate operation, multicolor photodetection and integration with a flexible substrate. This novel photodetector platform holds great prospects for next generation imaging applications and flexible optoelectronics.

Thesis Committee:

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Thesis Committee